


The Black Hole Accretion Disk in NGC4258: One of Nature's Most Beautiful Dynamical Systems

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 NGC 4258 Group

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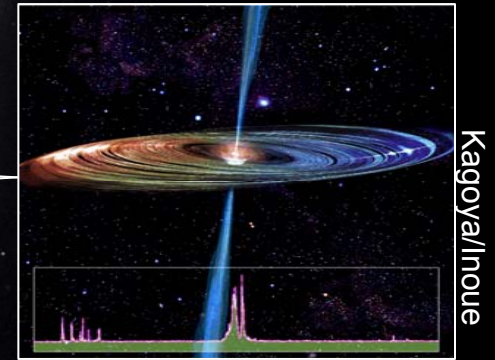
Student projects

Jim Herrnstein

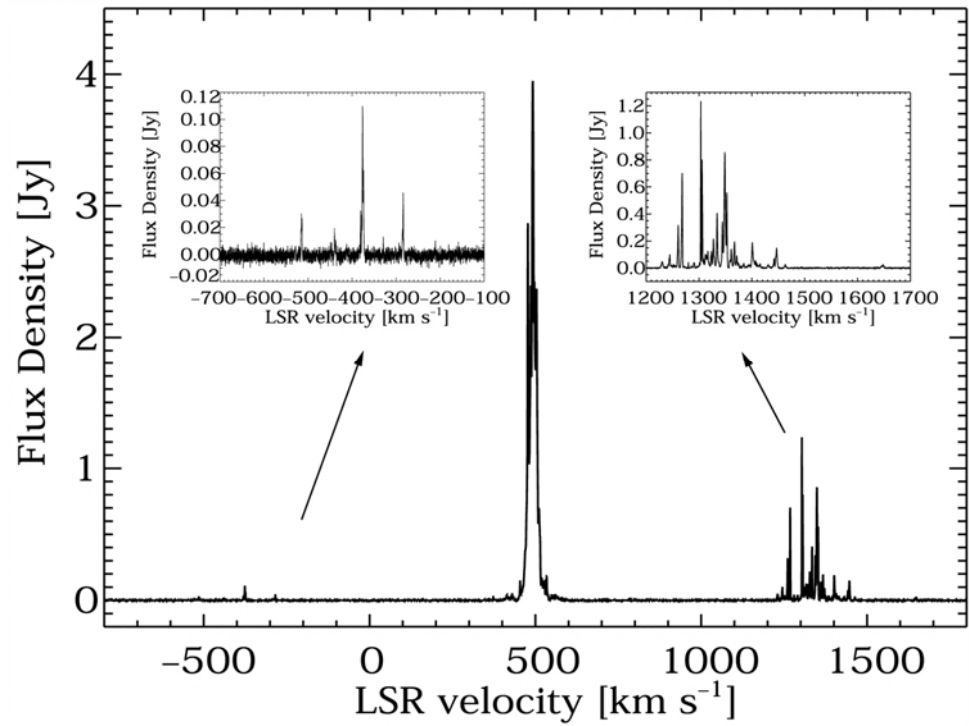
Adam Trotter

Ann Bragg

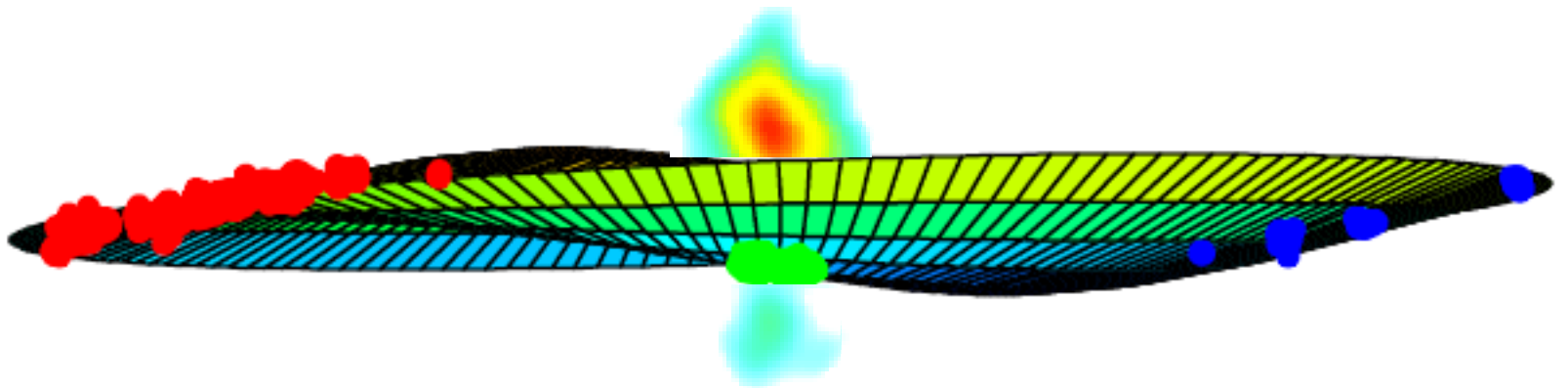
Maryam Modjaz

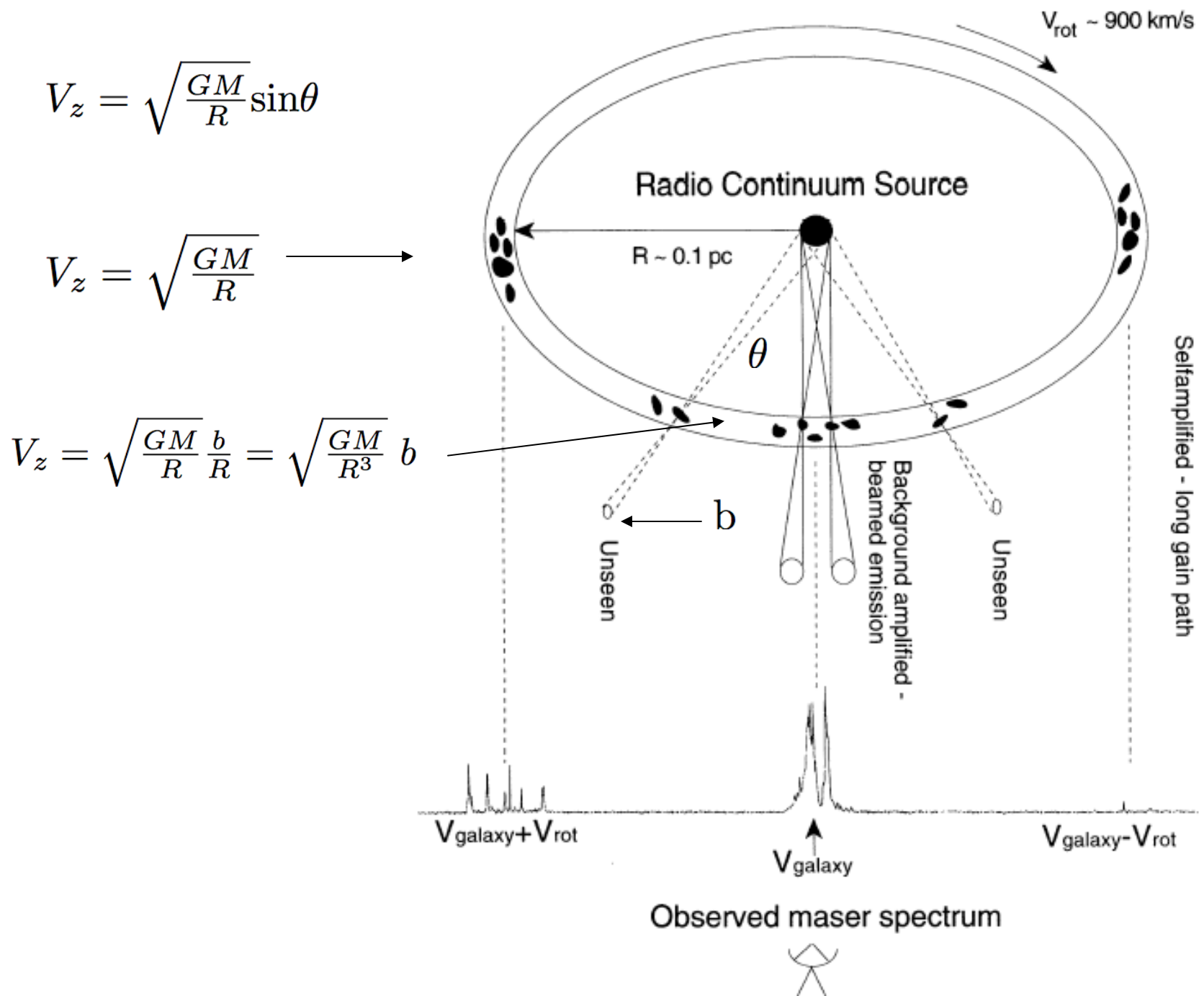


Optical: Slotnick, Slotnick & Block

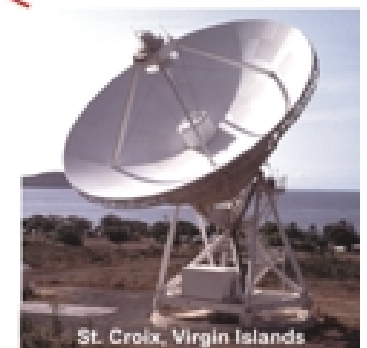
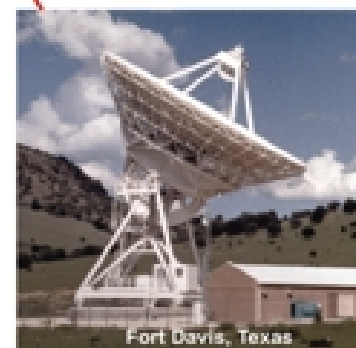
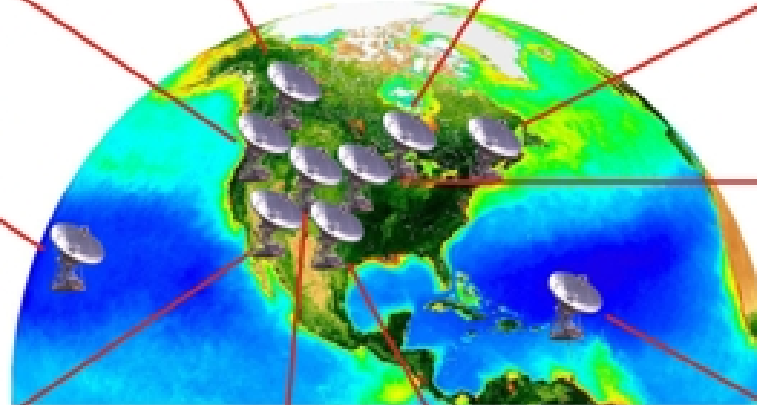


The Archetype: NGC 4258





VLBA



Angular resolution = $200 \mu\text{as}$ (0.006 pc at 7.2 Mpc)

Spectral resolution $< 1 \text{ kms}^{-1}$

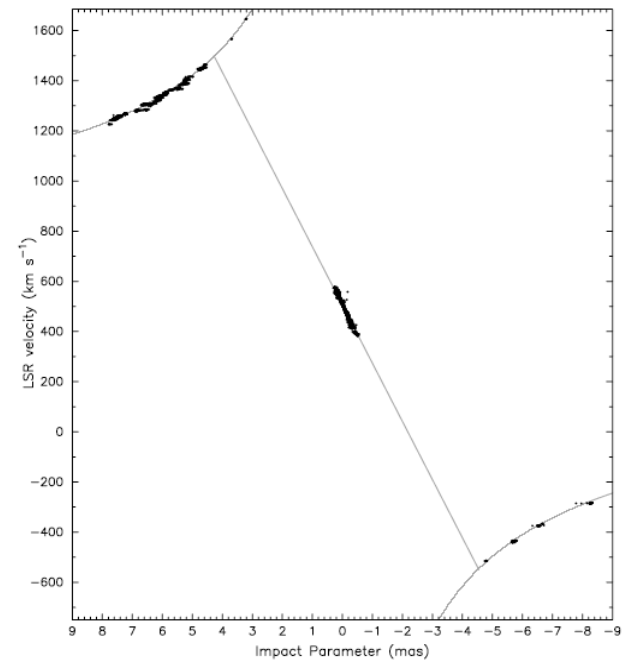
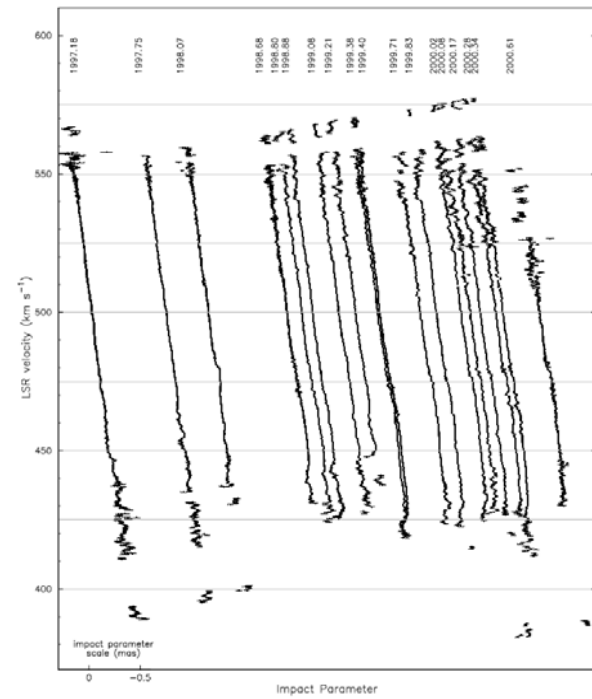
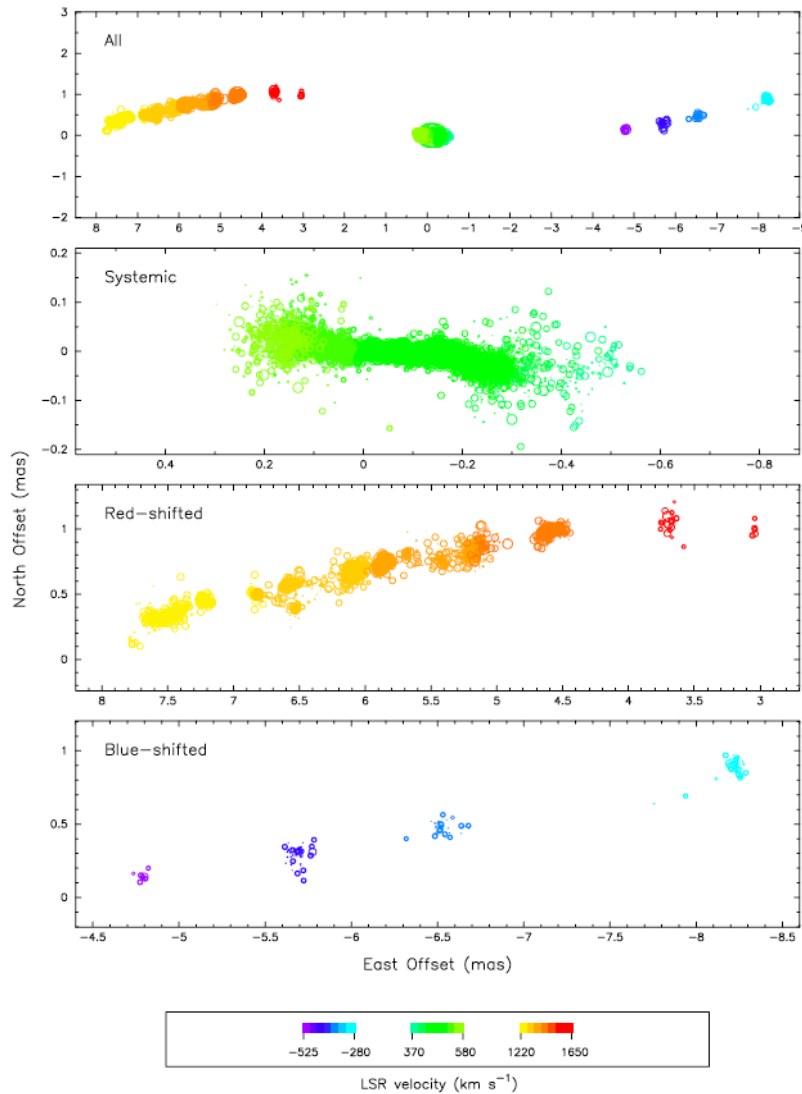
VLBI Monitoring of NGC4258 1997–2000

EPOCH	<u>Number of Channels Imaged</u>		
	Red	Systemic	Blue
BM056C (1997 Mar 06)*	727	1147	58
BM081A (1997 Oct 01) *	500	1108	20
BM081B (1998 Jan 27) *	725	1041	6
BM112A (1998 Sep 05)*	481	1022	—
BM112B (1998 Oct 18)	232	335	—
BM112C (1998 Nov 16)	—	324	36
BM112E (1999 Jan 28)	—	319	30
BM112F (1999 Mar 19)	207	293	—
BM112G (1999 May 18)	—	333	38
BM112H (1999 May 26)*	433	1140	25
BM112J (1999 Sep 15)	—	309	—
BM112K (1999 Oct 29)	205	353	—
BM112L (2000 Jan 07)	—	331	29
BM112M (2000 Jan 30)	169	316	—
BM112N (2000 Mar 04)	—	338	13
BM112O (2000 Apr 12)	158	322	—
BM112P (2000 May 04)	—	355	12
BG107 (2000 Aug 12)*	130	632	—

Total	3,967	10,018	267

* high sensitivity epoch

NGC 4258: 18 VLBI Epochs 1997–2000

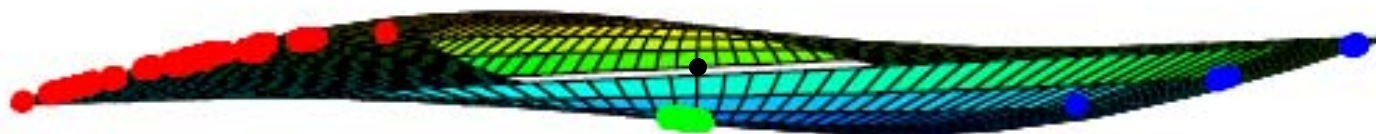


CfA Maser Group, Argon et al., 2007

NGC 4258

Observer's view

0.1 pc



Inclination warp (flattening of high velocity rotation curve): 8° across reds

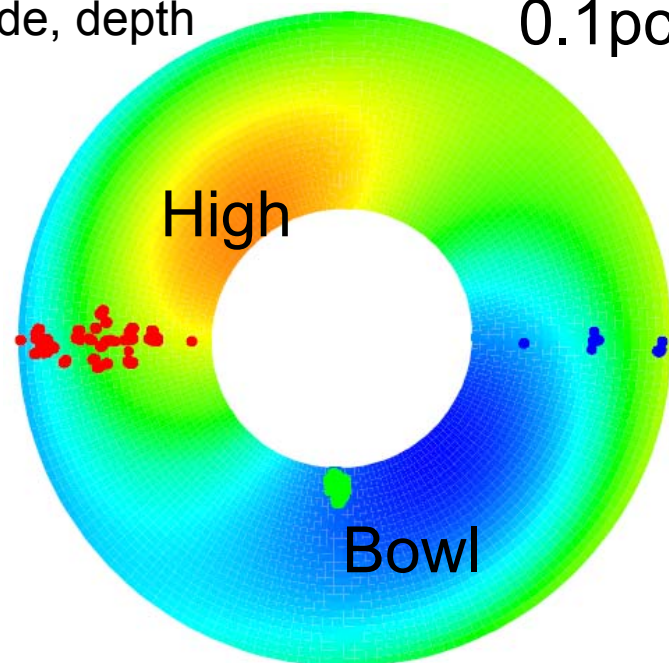
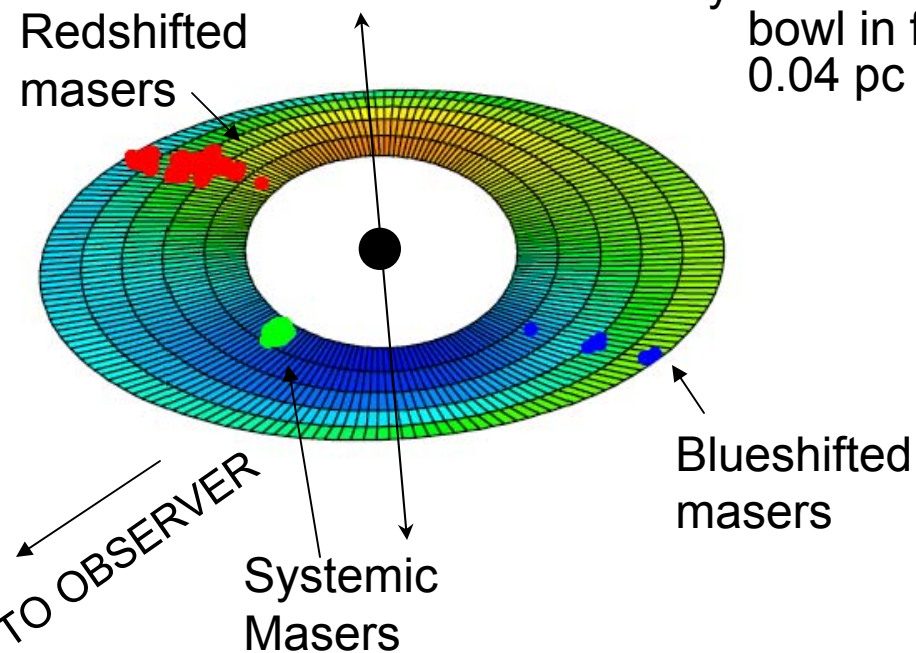
Position angle warp (declinations): 9° across reds

Disk obscuring much of central region. black hole mass 38 million M_\odot

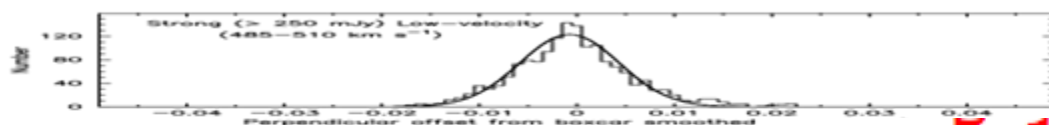
Systemic masers originate from bowl in front side of side, depth 0.04 pc

Top View

0.1 pc



Measurement of the Thickness of the Accretion Disk in the Vicinity of the Systemic Features

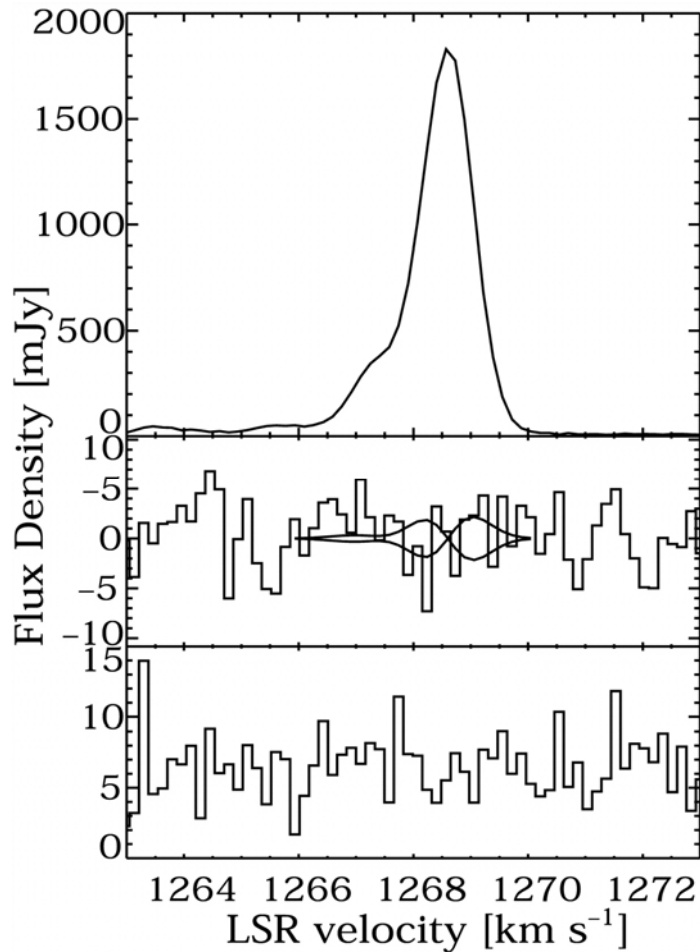


$$\sigma = 5.1 \mu\text{as}$$

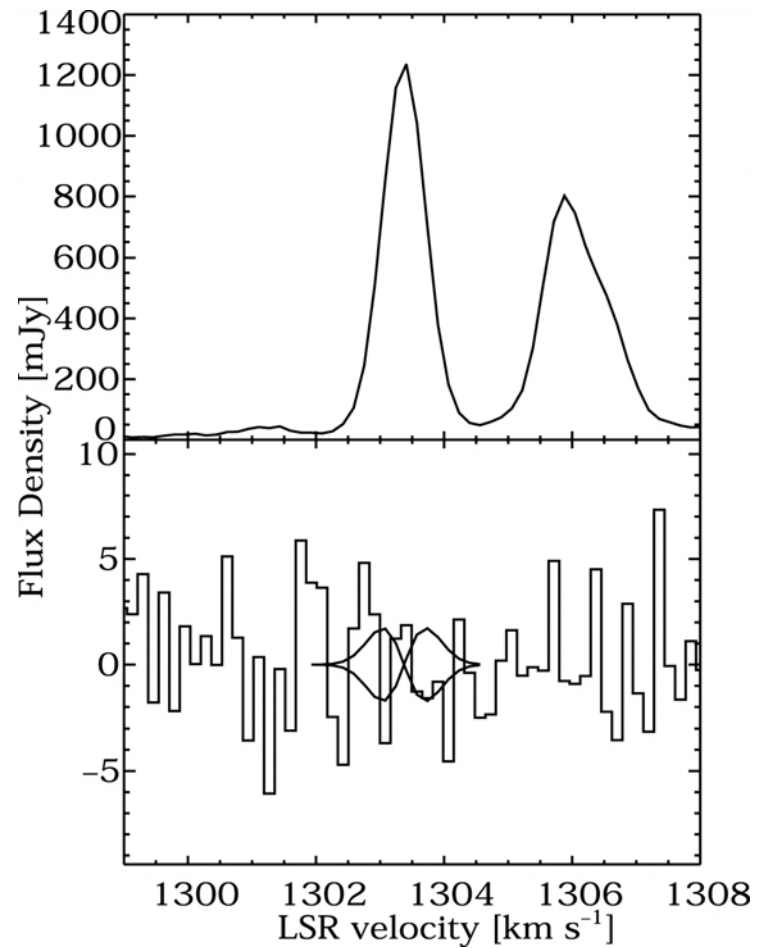
$$\rho = \rho_0 e^{-z^2/2\sigma^2} \quad \sigma = Rc_s/v$$

$$c_s = 1.5 \text{ km/s} \quad T = 600\text{K} \quad \sigma/R = 1.3 \times 10^{-3}$$

Search for Zeeman Splitting of Maser Features in NGC 4258 ($B < 30$ mG)

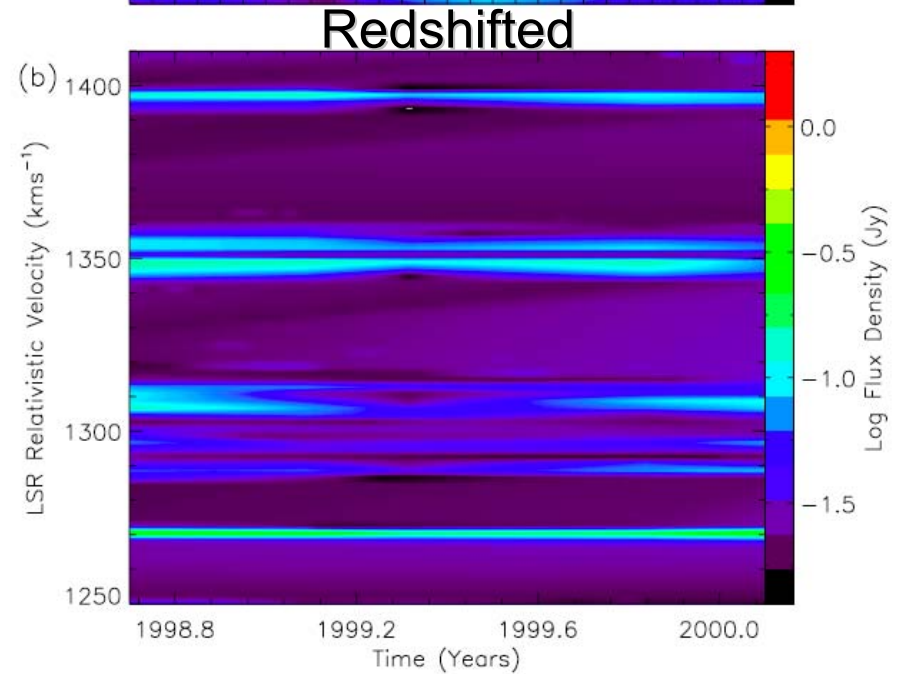
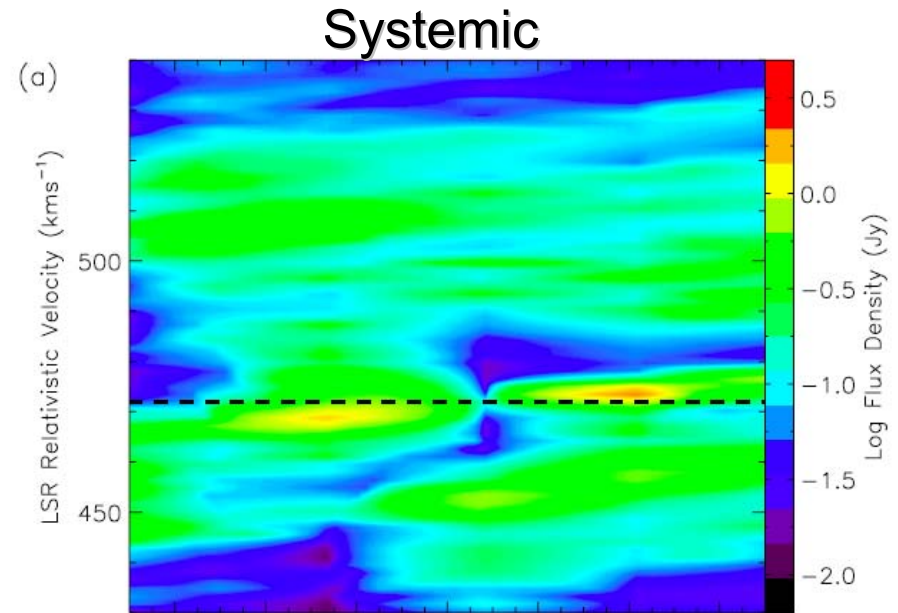
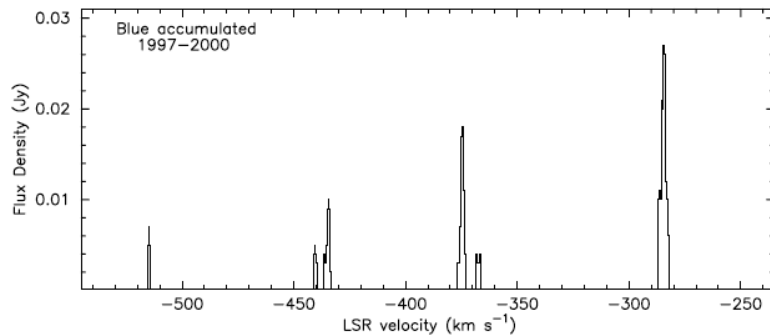
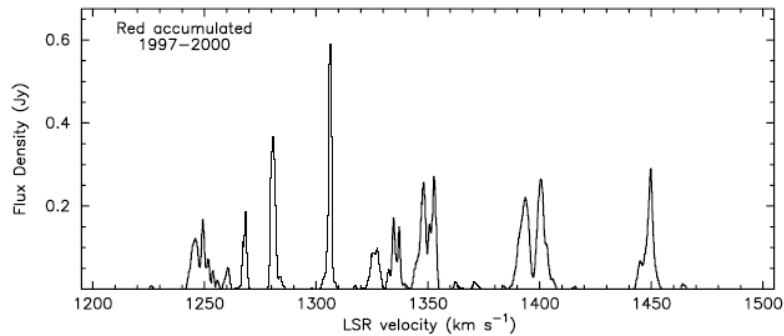
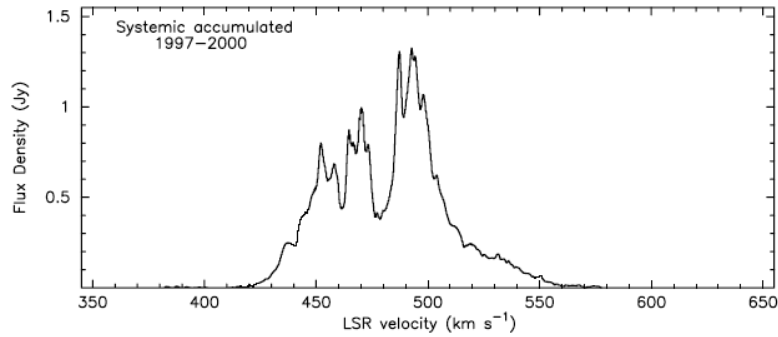


VLA Spectrum

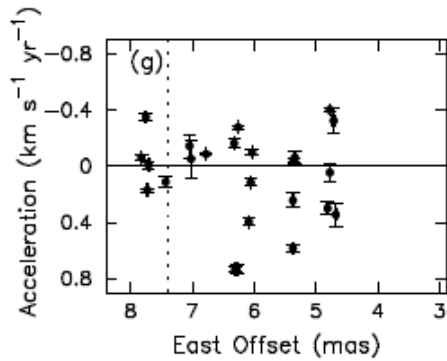
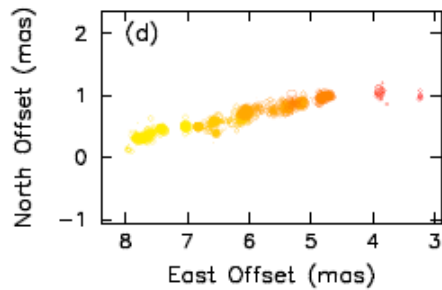
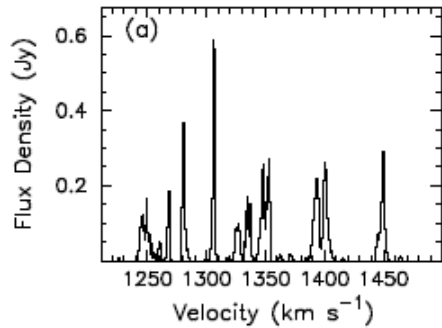


GBT Spectrum

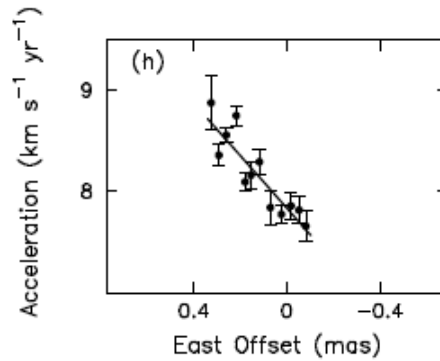
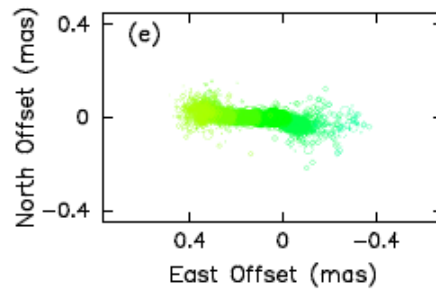
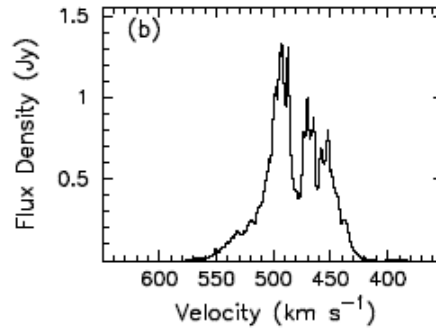
Average spectrum and velocity vs. time of maser features



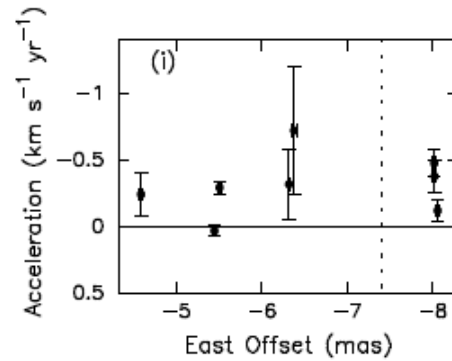
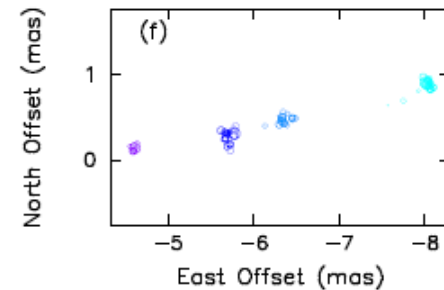
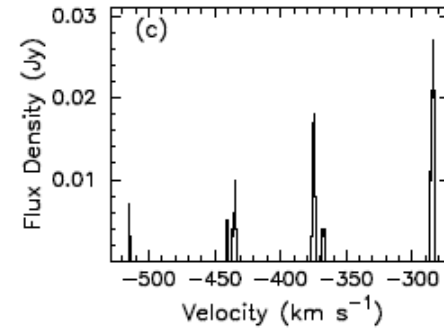
Red shifted



Systemic

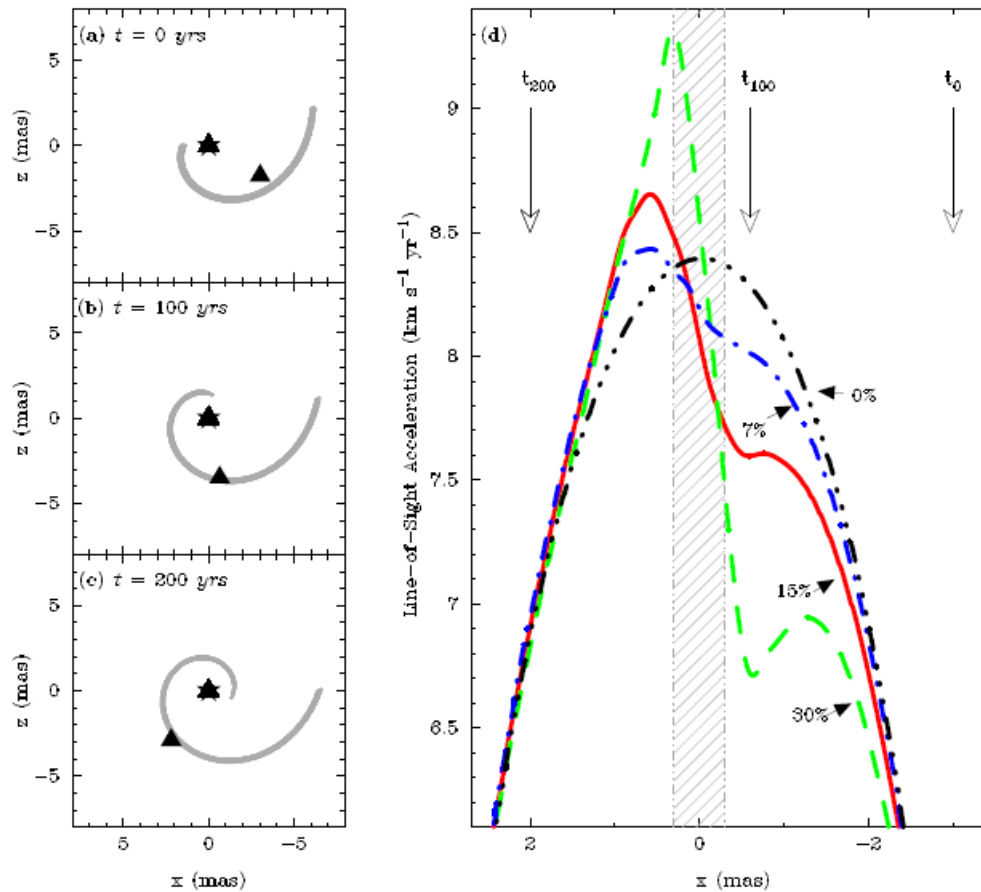


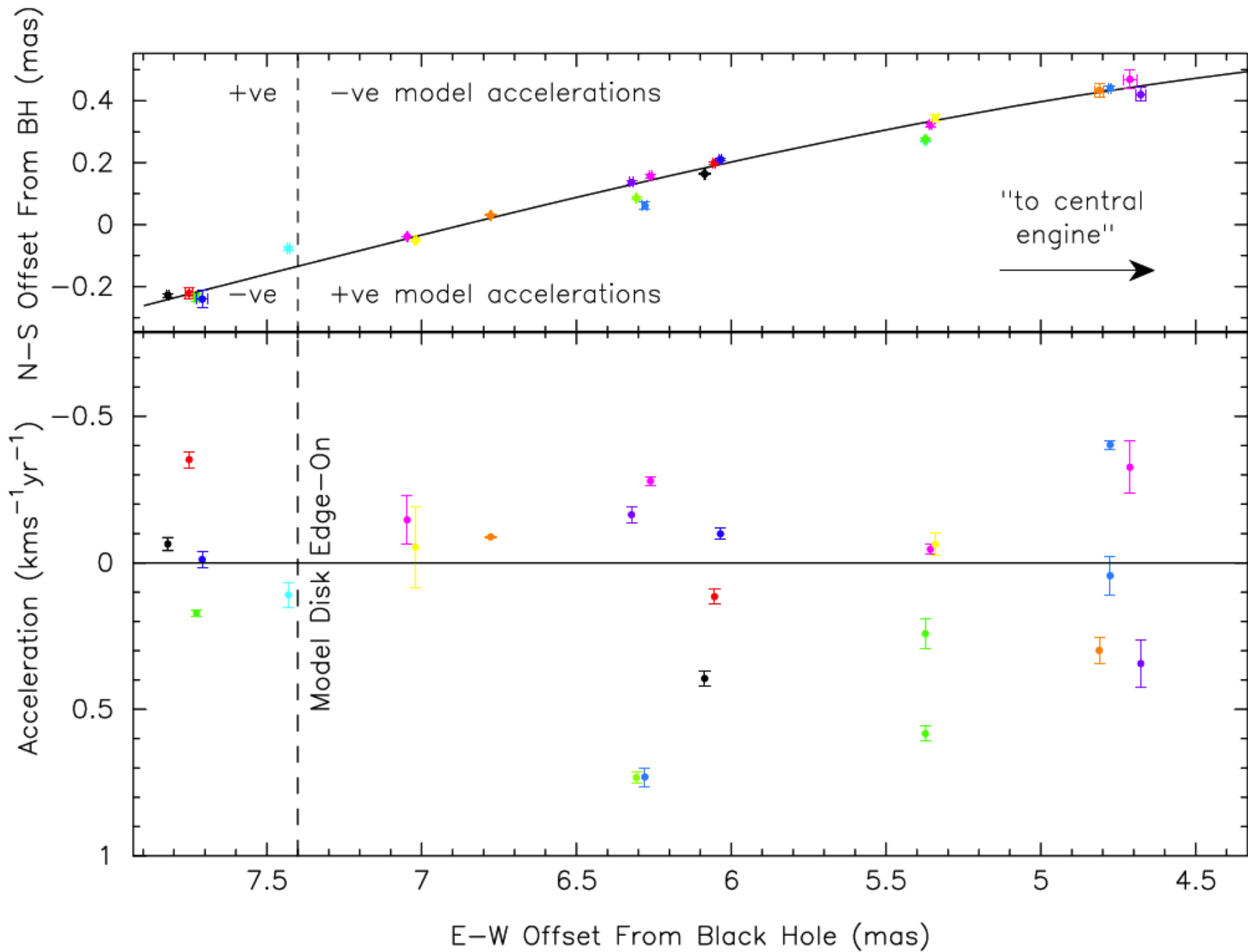
Blue shifted

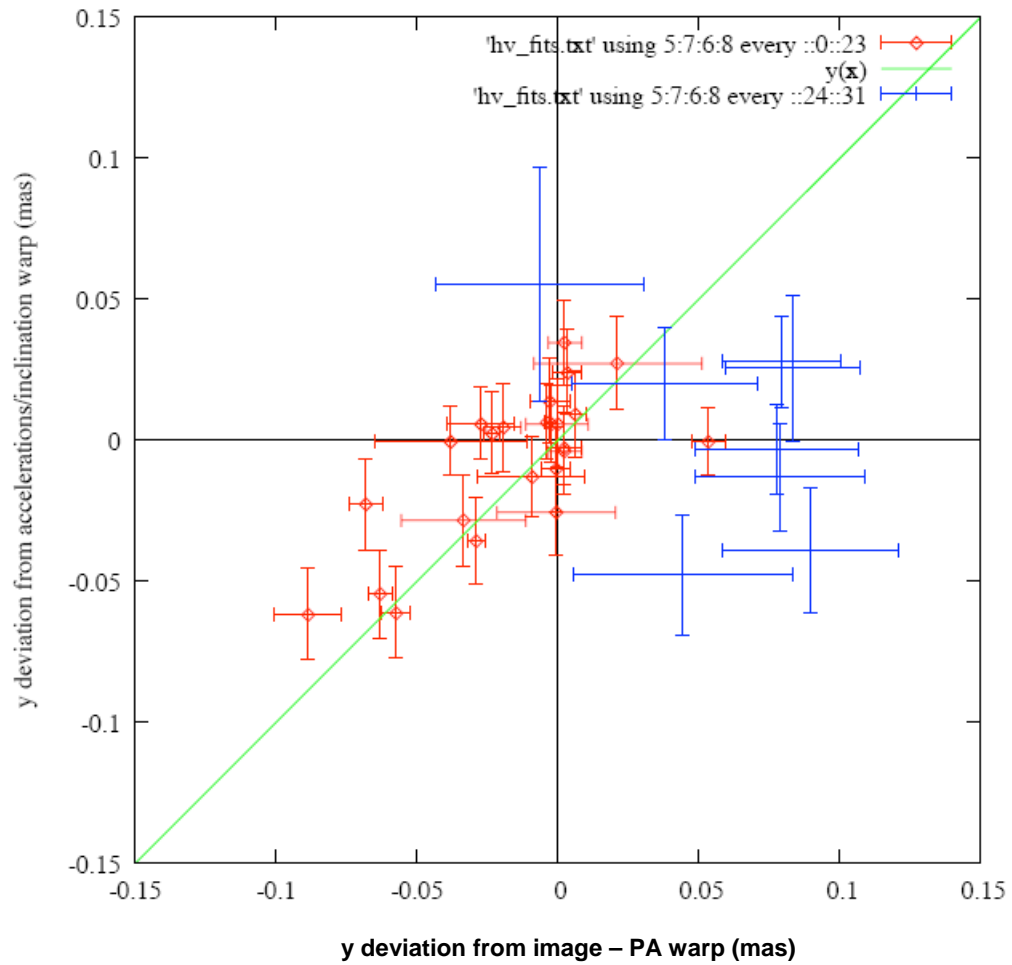


NGC4258: Velocities, Positions, and Accelerations

The Effect of a Spiral Arm on the Velocities of Systemic Maser Features

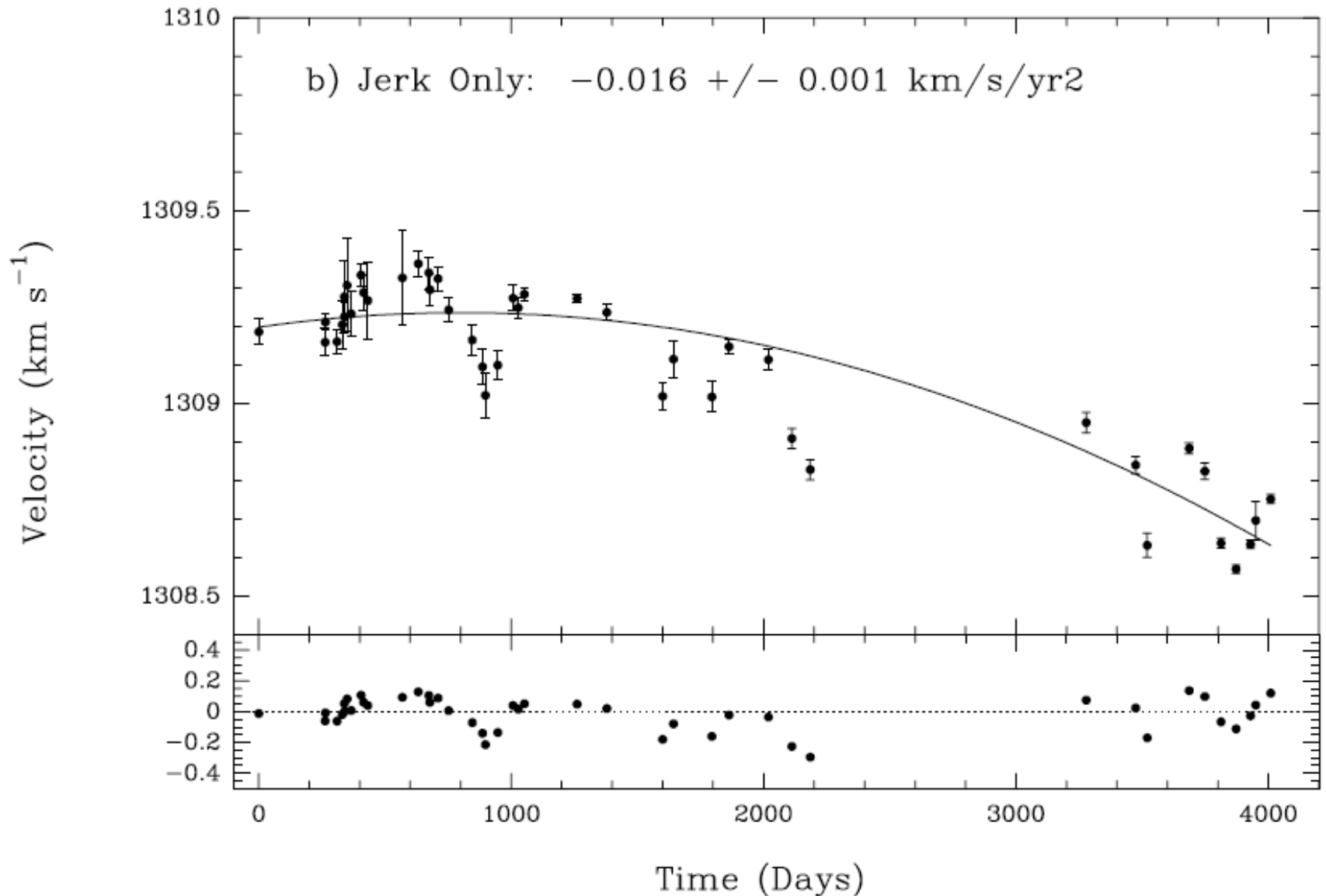






Humphreys et al., in preparation

Acceleration of the “1306” kms^{-1} Feature



Distance Measurements to NGC 4258

- **Masers**

7.2 +/- 0.3 +/-0.4 Mpc Herrnstein et al., Nature 1999

- **Cepheid Variables**

8.1 +/- 0.4 Mpc Maoz et al., 1999, Nature
(15 Cepheids)

7.8 +/- 0.3 +/- 0.5 Mpc Newman et al., 2001, Ap.J.
(same 15 Cepheids)

7.5 +/- 0.3 Mpc Macri et al., Ap.J. 652,1133 (300
Cepheids)

Conclusions

1. Bowl model well established:
 - a. 8 deg change in inclination across disk
 - b. Vertical displacements of HV features predicted by accelerations and inclination warp correlate well with observed vertical positions
2. Molecular disk thickness = 5.1 microarcsecs, $T = 600\text{K}$
3. Trends in accelerations in systemic features:
 - a. Change in annular radius of 5 percent, or
 - b. Interaction with spiral arm, or,
 - c. Confocal eccentric orbits
4. Magnetic field less than 30 mG
5. Evidence for periodic structure in high velocity features